

Class 08: Breast Cancer Mini Project

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Background

In today's class we will be employing all the R techniques for data and analysis that we have learned thus far - including the machine learning methods of clustering and PCA - to analyze real breast cancer biopsy data.

Data Import

The data is in CSV format:

```
wisc.df <- read.csv("WisconsinCancer.csv", row.names = 1)
```

wee peek at the data

```
head(wisc.df, 3)
```

	diagnosis	radius_mean	texture_mean	perimeter_mean	area_mean
842302	M	17.99	10.38	122.8	1001
842517	M	20.57	17.77	132.9	1326
84300903	M	19.69	21.25	130.0	1203
	smoothness_mean	compactness_mean	concavity_mean	concave.points_mean	
842302	0.11840	0.27760	0.3001		0.14710
842517	0.08474	0.07864	0.0869		0.07017
84300903	0.10960	0.15990	0.1974		0.12790
	symmetry_mean	fractal_dimension_mean	radius_se	texture_se	perimeter_se
842302	0.2419		0.07871	1.0950	0.9053
842517	0.1812		0.05667	0.5435	0.7339
84300903	0.2069		0.05999	0.7456	0.7869
	area_se	smoothness_se	compactness_se	concavity_se	concave.points_se
842302	153.40	0.006399	0.04904	0.05373	
842517	74.08	0.005225	0.01308	0.01860	
84300903	94.03	0.006150	0.04006	0.03832	
	symmetry_se	fractal_dimension_se	radius_worst	texture_worst	
842302	0.03003		0.006193	25.38	17.33
842517	0.01389		0.003532	24.99	23.41
84300903	0.02250		0.004571	23.57	25.53
	perimeter_worst	area_worst	smoothness_worst	compactness_worst	
842302	184.6	2019		0.1622	0.6656
842517	158.8	1956		0.1238	0.1866
84300903	152.5	1709		0.1444	0.4245
	concavity_worst	concave.points_worst	symmetry_worst		
842302	0.7119		0.2654	0.4601	
842517	0.2416		0.1860	0.2750	
84300903	0.4504		0.2430	0.3613	
	fractal_dimension_worst				
842302		0.11890			
842517		0.08902			
84300903		0.08758			

Q1. How many observations are in this dataset?

```
nrow(wisc.df)
```

```
[1] 569
```

Q2. How many of the observations have a malignant diagnosis?

```
table(wisc.df$diagnosis)
```

```
  B    M  
357 212
```

Q3. How many variables/features in the data are suffixed with `_mean`?

```
length(grep("_mean", colnames(wisc.df)))
```

```
[1] 10
```

We need to remove the `diagnosis` column before we do any further analysis of this dataset - we don't want to pass this to PCA etc. We will save it as a separate vector that we can use later to compare our findings to those of experts...

```
wisc.data <- wisc.df[,-1]  
diagnosis <- wisc.df$diagnosis
```

Principal Component Analysis (PCA)

The main function in base R is called `prcomp()` we will use the optional argument `scale=TRUE` here as the data columns/features/dimensions are very different scales in the original data set.

```
wisc.pr <- prcomp(wisc.data, scale=T)
```

```
attributes(wisc.pr)
```

```
$names  
[1] "sdev"      "rotation" "center"    "scale"     "x"
```

```
$class  
[1] "prcomp"
```

```
summary(wisc.pr)
```

Importance of components:

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Standard deviation	3.6444	2.3857	1.67867	1.40735	1.28403	1.09880	0.82172
Proportion of Variance	0.4427	0.1897	0.09393	0.06602	0.05496	0.04025	0.02251
Cumulative Proportion	0.4427	0.6324	0.72636	0.79239	0.84734	0.88759	0.91010
	PC8	PC9	PC10	PC11	PC12	PC13	PC14
Standard deviation	0.69037	0.6457	0.59219	0.5421	0.51104	0.49128	0.39624
Proportion of Variance	0.01589	0.0139	0.01169	0.0098	0.00871	0.00805	0.00523
Cumulative Proportion	0.92598	0.9399	0.95157	0.9614	0.97007	0.97812	0.98335
	PC15	PC16	PC17	PC18	PC19	PC20	PC21
Standard deviation	0.30681	0.28260	0.24372	0.22939	0.22244	0.17652	0.1731
Proportion of Variance	0.00314	0.00266	0.00198	0.00175	0.00165	0.00104	0.0010
Cumulative Proportion	0.98649	0.98915	0.99113	0.99288	0.99453	0.99557	0.9966
	PC22	PC23	PC24	PC25	PC26	PC27	PC28
Standard deviation	0.16565	0.15602	0.1344	0.12442	0.09043	0.08307	0.03987
Proportion of Variance	0.00091	0.00081	0.0006	0.00052	0.00027	0.00023	0.00005
Cumulative Proportion	0.99749	0.99830	0.9989	0.99942	0.99969	0.99992	0.99997
	PC29	PC30					
Standard deviation	0.02736	0.01153					
Proportion of Variance	0.00002	0.00000					
Cumulative Proportion	1.00000	1.00000					

Q4. From your results, what proportion of the original variance is captured by the first principal component (PC1)?

0.4427 = 44.27%

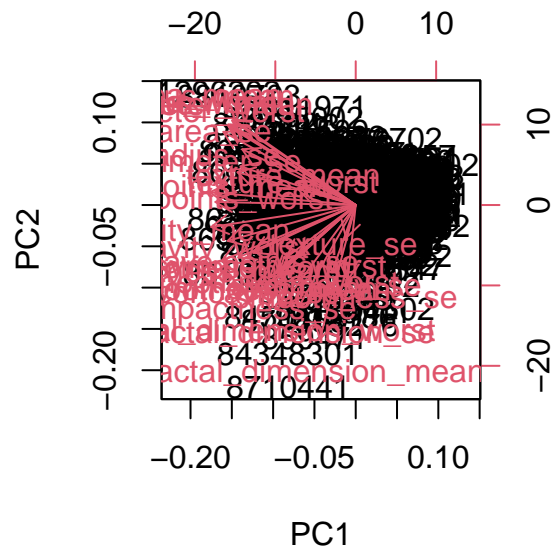
Q5. How many principal components (PCs) are required to describe at least 70% of the original variance in the data?

3 principal components

Q6. How many principal components (PCs) are required to describe at least 90% of the original variance in the data?

7 principal components

```
biplot(wisc.pr)
```

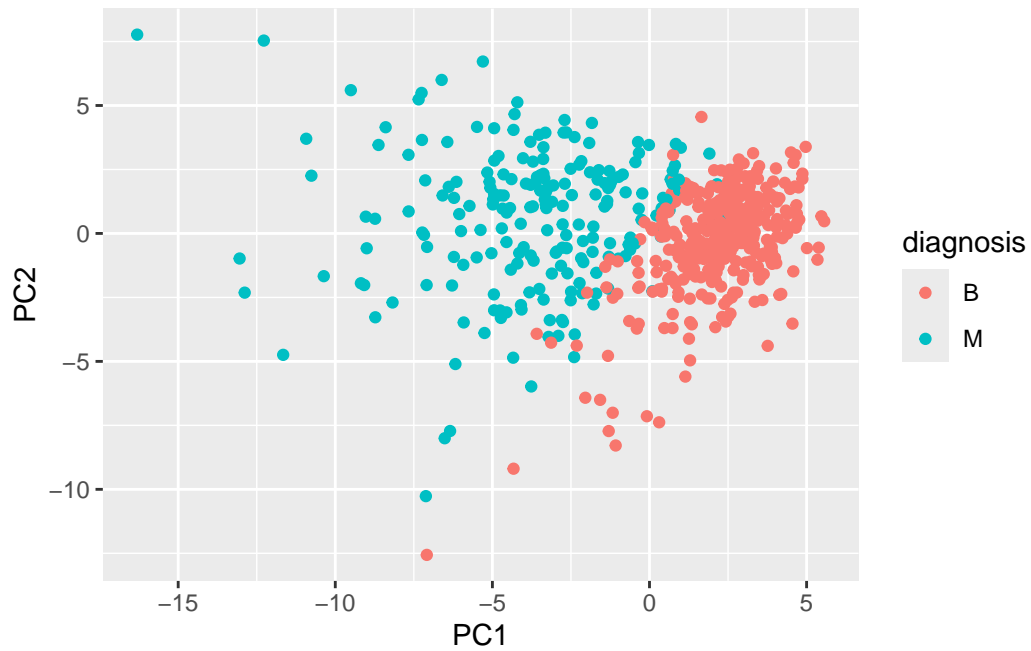


Q7. What stands out to you about this plot? Is it easy or difficult to understand? Why?

The biplot is very cluttered and difficult to interpret. With so many observations and variables, the points and variable arrows overlap heavily, making it hard to see patterns or understand how variables contribute to the principal components.

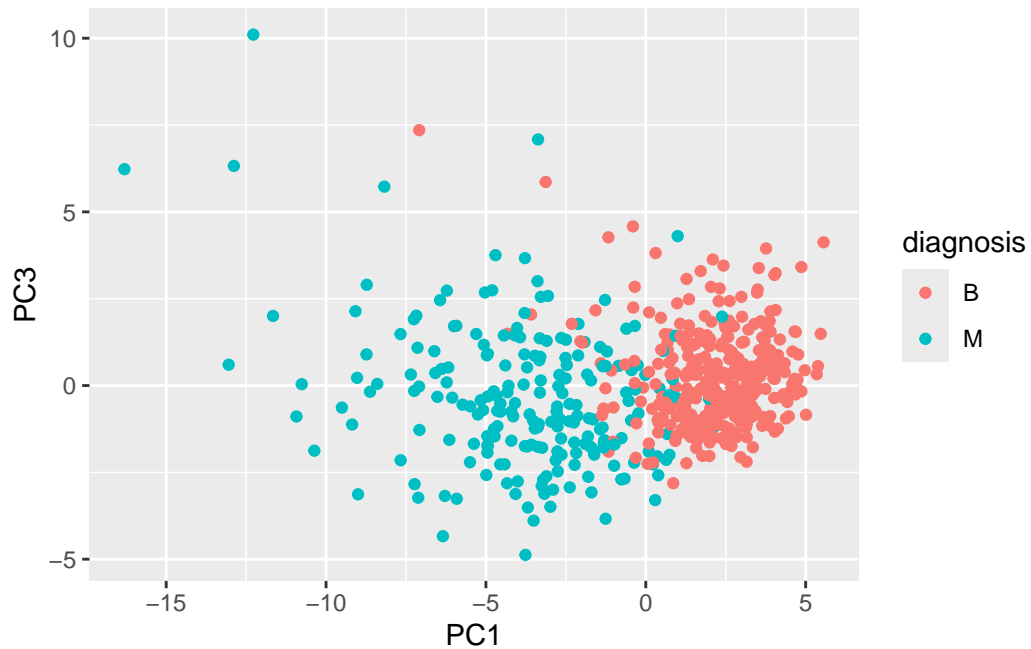
```
library(ggplot2)

ggplot(wisc.pr$x) +
  aes(PC1, PC2, col=diagnosis) +
  geom_point()
```



Q8. Generate a similar plot for principal components 1 and 3. What do you notice about these plots?

```
ggplot(wisc.pr$x) +  
  aes(PC1, PC3, col=diagnosis) +  
  geom_point()
```



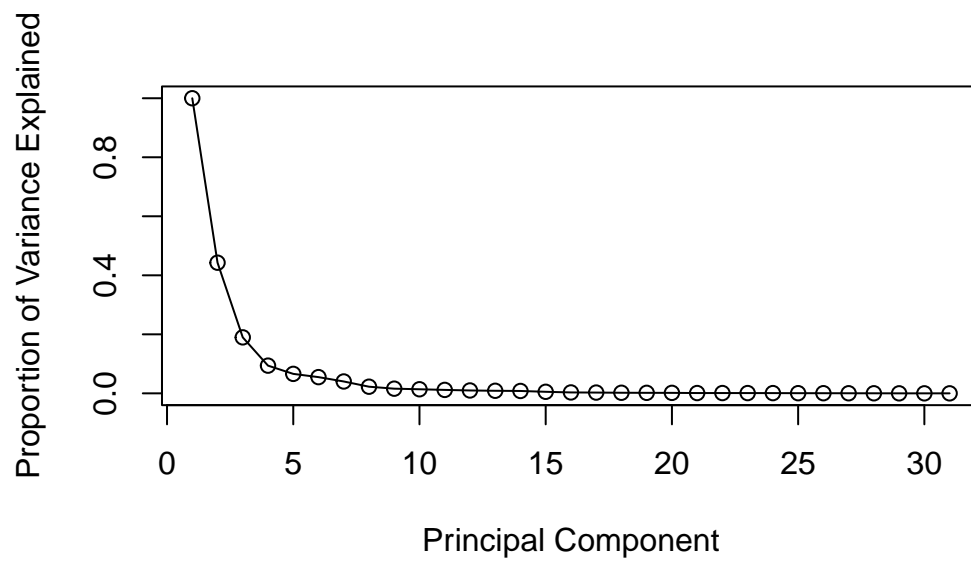
Variance explained

```
pr.var <- wisc.pr$sdev^2
head(pr.var)
```

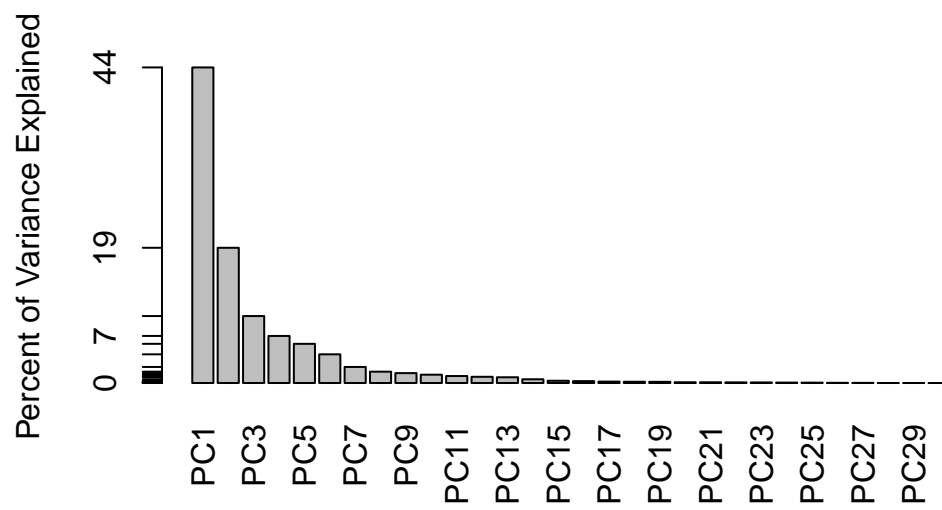
```
[1] 13.281608  5.691355  2.817949  1.980640  1.648731  1.207357
```

```
pve <- pr.var / sum(pr.var)
```

```
plot(c(1, pve),
     xlab = "Principal Component",
     ylab = "Proportion of Variance Explained",
     ylim = c(0, 1),
     type = "o")
```



```
barplot(pve,  
        ylab = "Percent of Variance Explained",  
        names.arg = paste0("PC", 1:length(pve)),  
        las = 2,  
        axes = FALSE)  
axis(2, at = pve, labels = round(pve, 2) * 100)
```

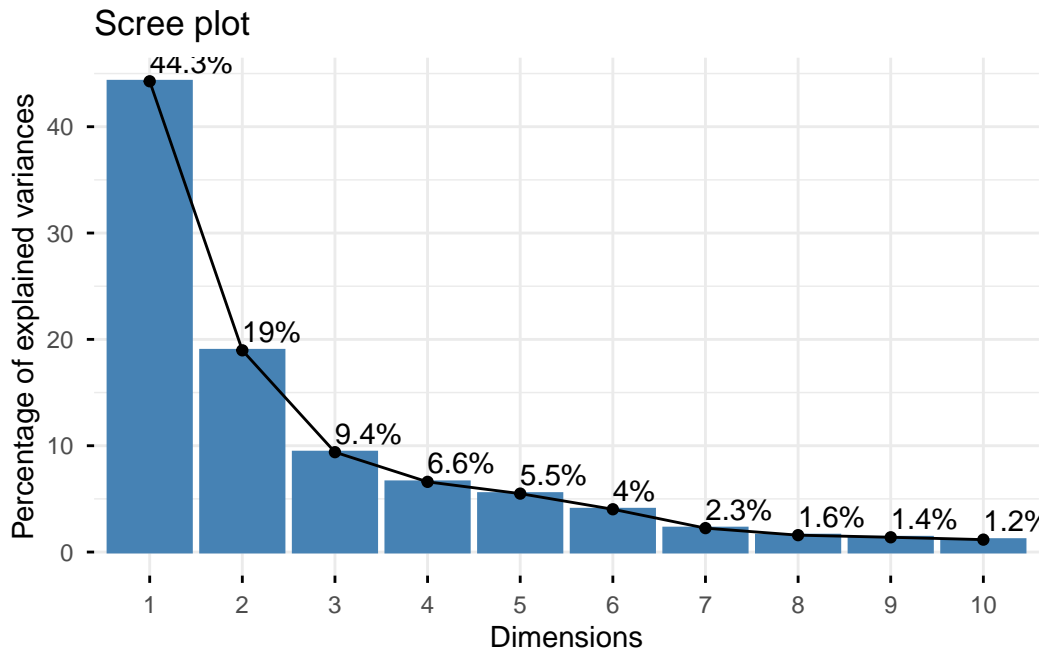
```
#install.packages("factoextra")
```

```
library(factoextra)
```

Welcome! Want to learn more? See two factoextra-related books at <https://goo.gl/ve3WBa>

```
fviz_eig(wisc.pr, addlabels = TRUE)
```

Warning in geom_bar(stat = "identity", fill = barfill, color = barcolor, :
Ignoring empty aesthetic: `width`.



Q9. For the first principal component, what is the component of the loading vector (i.e. `wisc.pr$rotation[,1]`) for the feature `concave.points_mean`? This tells us how much this original feature contributes to the first PC. Are there any features with larger contributions than this one?

```
wisc.pr$rotation
```

	PC1	PC2	PC3	PC4
radius_mean	-0.21890244	0.233857132	-0.008531243	0.041408962
texture_mean	-0.10372458	0.059706088	0.064549903	-0.603050001
perimeter_mean	-0.22753729	0.215181361	-0.009314220	0.041983099
area_mean	-0.22099499	0.231076711	0.028699526	0.053433795
smoothness_mean	-0.14258969	-0.186113023	-0.104291904	0.159382765
compactness_mean	-0.23928535	-0.151891610	-0.074091571	0.031794581
concavity_mean	-0.25840048	-0.060165363	0.002733838	0.019122753
concave.points_mean	-0.26085376	0.034767500	-0.025563541	0.065335944
symmetry_mean	-0.13816696	-0.190348770	-0.040239936	0.067124984
fractal_dimension_mean	-0.06436335	-0.366575471	-0.022574090	0.048586765
radius_se	-0.20597878	0.105552152	0.268481387	0.097941242
texture_se	-0.01742803	-0.089979682	0.374633665	-0.359855528
perimeter_se	-0.21132592	0.089457234	0.266645367	0.088992415
area_se	-0.20286964	0.152292628	0.216006528	0.108205039

smoothness_se	-0.01453145	-0.204430453	0.308838979	0.044664180
compactness_se	-0.17039345	-0.232715896	0.154779718	-0.027469363
concavity_se	-0.15358979	-0.197207283	0.176463743	0.001316880
concave.points_se	-0.18341740	-0.130321560	0.224657567	0.074067335
symmetry_se	-0.04249842	-0.183848000	0.288584292	0.044073351
fractal_dimension_se	-0.10256832	-0.280092027	0.211503764	0.015304750
radius_worst	-0.22799663	0.219866379	-0.047506990	0.015417240
texture_worst	-0.10446933	0.045467298	-0.042297823	-0.632807885
perimeter_worst	-0.23663968	0.199878428	-0.048546508	0.013802794
area_worst	-0.22487053	0.219351858	-0.011902318	0.025894749
smoothness_worst	-0.12795256	-0.172304352	-0.259797613	0.017652216
compactness_worst	-0.21009588	-0.143593173	-0.236075625	-0.091328415
concavity_worst	-0.22876753	-0.097964114	-0.173057335	-0.073951180
concave.points_worst	-0.25088597	0.008257235	-0.170344076	0.006006996
symmetry_worst	-0.12290456	-0.141883349	-0.271312642	-0.036250695
fractal_dimension_worst	-0.13178394	-0.275339469	-0.232791313	-0.077053470
	PC5	PC6	PC7	PC8
radius_mean	-0.037786354	0.0187407904	-0.1240883403	0.007452296
texture_mean	0.049468850	-0.0321788366	0.0113995382	-0.130674825
perimeter_mean	-0.037374663	0.0173084449	-0.1144770573	0.018687258
area_mean	-0.010331251	-0.0018877480	-0.0516534275	-0.034673604
smoothness_mean	0.365088528	-0.2863744966	-0.1406689928	0.288974575
compactness_mean	-0.011703971	-0.0141309489	0.0309184960	0.151396350
concavity_mean	-0.086375412	-0.0093441809	-0.1075204434	0.072827285
concave.points_mean	0.043861025	-0.0520499505	-0.1504822142	0.152322414
symmetry_mean	0.305941428	0.3564584607	-0.0938911345	0.231530989
fractal_dimension_mean	0.044424360	-0.1194306679	0.2957600240	0.177121441
radius_se	0.154456496	-0.0256032561	0.3124900373	-0.022539967
texture_se	0.191650506	-0.0287473145	-0.0907553556	0.475413139
perimeter_se	0.120990220	0.0018107150	0.3146403902	0.011896690
area_se	0.127574432	-0.0428639079	0.3466790028	-0.085805135
smoothness_se	0.232065676	-0.3429173935	-0.2440240556	-0.573410232
compactness_se	-0.279968156	0.0691975186	0.0234635340	-0.117460157
concavity_se	-0.353982091	0.0563432386	-0.2088237897	-0.060566501
concave.points_se	-0.195548089	-0.0312244482	-0.3696459369	0.108319309
symmetry_se	0.252868765	0.4902456426	-0.0803822539	-0.220149279
fractal_dimension_se	-0.263297438	-0.0531952674	0.1913949726	-0.011168188
radius_worst	0.004406592	-0.0002906849	-0.0097099360	-0.042619416
texture_worst	0.092883400	-0.0500080613	0.0098707439	-0.036251636
perimeter_worst	-0.007454151	0.0085009872	-0.0004457267	-0.030558534
area_worst	0.027390903	-0.0251643821	0.0678316595	-0.079394246
smoothness_worst	0.324435445	-0.3692553703	-0.1088308865	-0.205852191
compactness_worst	-0.121804107	0.0477057929	0.1404729381	-0.084019659

concavity_worst	-0.188518727	0.0283792555	-0.0604880561	-0.072467871
concave.points_worst	-0.043332069	-0.0308734498	-0.1679666187	0.036170795
symmetry_worst	0.244558663	0.4989267845	-0.0184906298	-0.228225053
fractal_dimension_worst	-0.094423351	-0.0802235245	0.3746576261	-0.048360667
	PC9	PC10	PC11	PC12
radius_mean	-0.223109764	0.095486443	-0.04147149	0.051067457
texture_mean	0.112699390	0.240934066	0.30224340	0.254896423
perimeter_mean	-0.223739213	0.086385615	-0.01678264	0.038926106
area_mean	-0.195586014	0.074956489	-0.11016964	0.065437508
smoothness_mean	0.006424722	-0.069292681	0.13702184	0.316727211
compactness_mean	-0.167841425	0.012936200	0.30800963	-0.104017044
concavity_mean	0.040591006	-0.135602298	-0.12419024	0.065653480
concave.points_mean	-0.111971106	0.008054528	0.07244603	0.042589267
symmetry_mean	0.256040084	0.572069479	-0.16305408	-0.288865504
fractal_dimension_mean	-0.123740789	0.081103207	0.03804827	0.236358988
radius_se	0.249985002	-0.049547594	0.02535702	-0.016687915
texture_se	-0.246645397	-0.289142742	-0.34494446	-0.306160423
perimeter_se	0.227154024	-0.114508236	0.16731877	-0.101446828
area_se	0.229160015	-0.091927889	-0.05161946	-0.017679218
smoothness_se	-0.141924890	0.160884609	-0.08420621	-0.294710053
compactness_se	-0.145322810	0.043504866	0.20688568	-0.263456509
concavity_se	0.358107079	-0.141276243	-0.34951794	0.251146975
concave.points_se	0.272519886	0.086240847	0.34237591	-0.006458751
symmetry_se	-0.304077200	-0.316529830	0.18784404	0.320571348
fractal_dimension_se	-0.213722716	0.367541918	-0.25062479	0.276165974
radius_worst	-0.112141463	0.077361643	-0.10506733	0.039679665
texture_worst	0.103341204	0.029550941	-0.01315727	0.079797450
perimeter_worst	-0.109614364	0.050508334	-0.05107628	-0.008987738
area_worst	-0.080732461	0.069921152	-0.18459894	0.048088657
smoothness_worst	0.112315904	-0.128304659	-0.14389035	0.056514866
compactness_worst	-0.100677822	-0.172133632	0.19742047	-0.371662503
concavity_worst	0.161908621	-0.311638520	-0.18501676	-0.087034532
concave.points_worst	0.060488462	-0.076648291	0.11777205	-0.068125354
symmetry_worst	0.064637806	-0.029563075	-0.15756025	0.044033503
fractal_dimension_worst	-0.134174175	0.012609579	-0.11828355	-0.034731693
	PC13	PC14	PC15	PC16
radius_mean	0.01196721	0.059506135	-0.051118775	-0.15058388
texture_mean	0.20346133	-0.021560100	-0.107922421	-0.15784196
perimeter_mean	0.04410950	0.048513812	-0.039902936	-0.11445396
area_mean	0.06737574	0.010830829	0.013966907	-0.13244803
smoothness_mean	0.04557360	0.445064860	-0.118143364	-0.20461325
compactness_mean	0.22928130	0.008101057	0.230899962	0.17017837
concavity_mean	0.38709081	-0.189358699	-0.128283732	0.26947021

concave.points_mean	0.13213810	-0.244794768	-0.217099194	0.38046410
symmetry_mean	0.18993367	0.030738856	-0.073961707	-0.16466159
fractal_dimension_mean	0.10623908	-0.377078865	0.517975705	-0.04079279
radius_se	-0.06819523	0.010347413	-0.110050711	0.05890572
texture_se	-0.16822238	-0.010849347	0.032752721	-0.03450040
perimeter_se	-0.03784399	-0.045523718	-0.008268089	0.02651665
area_se	0.05606493	0.083570718	-0.046024366	0.04115323
smoothness_se	0.15044143	-0.201152530	0.018559465	-0.05803906
compactness_se	0.01004017	0.491755932	0.168209315	0.18983090
concavity_se	0.15878319	0.134586924	0.250471408	-0.12542065
concave.points_se	-0.49402674	-0.199666719	0.062079344	-0.19881035
symmetry_se	0.01033274	-0.046864383	-0.113383199	-0.15771150
fractal_dimension_se	-0.24045832	0.145652466	-0.353232211	0.26855388
radius_worst	-0.13789053	0.023101281	0.166567074	-0.08156057
texture_worst	-0.08014543	0.053430792	0.101115399	0.18555785
perimeter_worst	-0.09696571	0.012219382	0.182755198	-0.05485705
area_worst	-0.10116061	-0.006685465	0.314993600	-0.09065339
smoothness_worst	-0.20513034	0.162235443	0.046125866	0.14555166
compactness_worst	0.01227931	0.166470250	-0.049956014	-0.15373486
concavity_worst	0.21798433	-0.066798931	-0.204835886	-0.21502195
concave.points_worst	-0.25438749	-0.276418891	-0.169499607	0.17814174
symmetry_worst	-0.25653491	0.005355574	0.139888394	0.25789401
fractal_dimension_worst	-0.17281424	-0.212104110	-0.256173195	-0.40555649
	PC17	PC18	PC19	PC20
radius_mean	0.202924255	0.1467123385	0.22538466	-0.049698664
texture_mean	-0.038706119	-0.0411029851	0.02978864	-0.244134993
perimeter_mean	0.194821310	0.1583174548	0.23959528	-0.017665012
area_mean	0.255705763	0.2661681046	-0.02732219	-0.090143762
smoothness_mean	0.167929914	-0.3522268017	-0.16456584	0.017100960
compactness_mean	-0.020307708	0.0077941384	0.28422236	0.488686329
concavity_mean	-0.001598353	-0.0269681105	0.00226636	-0.033387086
concave.points_mean	0.034509509	-0.0828277367	-0.15497236	-0.235407606
symmetry_mean	-0.191737848	0.1733977905	-0.05881116	0.026069156
fractal_dimension_mean	0.050225246	0.0878673570	-0.05815705	-0.175637222
radius_se	-0.139396866	-0.2362165319	0.17588331	-0.090800503
texture_se	0.043963016	-0.0098586620	0.03600985	-0.071659988
perimeter_se	-0.024635639	-0.0259288003	0.36570154	-0.177250625
area_se	0.334418173	0.3049069032	-0.41657231	0.274201148
smoothness_se	0.139595006	-0.2312599432	-0.01326009	0.090061477
compactness_se	-0.008246477	0.1004742346	-0.24244818	-0.461098220
concavity_se	0.084616716	-0.0001954852	0.12638102	0.066946174
concave.points_se	0.108132263	0.0460549116	-0.01216430	0.068868294
symmetry_se	-0.274059129	0.1870147640	-0.08903929	0.107385289

fractal_dimension_se	-0.122733398	-0.0598230982	0.08660084	0.222345297
radius_worst	-0.240049982	-0.2161013526	0.01366130	-0.005626909
texture_worst	0.069365185	0.0583984505	-0.07586693	0.300599798
perimeter_worst	-0.234164147	-0.1885435919	0.09081325	0.011003858
area_worst	-0.273399584	-0.1420648558	-0.41004720	0.060047387
smoothness_worst	-0.278030197	0.5015516751	0.23451384	-0.129723903
compactness_worst	-0.004037123	-0.0735745143	0.02020070	0.229280589
concavity_worst	-0.191313419	-0.1039079796	-0.04578612	-0.046482792
concave.points_worst	-0.075485316	0.0758138963	-0.26022962	0.033022340
symmetry_worst	0.430658116	-0.2787138431	0.11725053	-0.116759236
fractal_dimension_worst	0.159394300	0.0235647497	-0.01149448	-0.104991974
	PC21	PC22	PC23	PC24
radius_mean	-0.0685700057	-0.07292890	-0.0985526942	-0.18257944
texture_mean	0.4483694667	-0.09480063	-0.0005549975	0.09878679
perimeter_mean	-0.0697690429	-0.07516048	-0.0402447050	-0.11664888
area_mean	-0.0184432785	-0.09756578	0.0077772734	0.06984834
smoothness_mean	-0.1194917473	-0.06382295	-0.0206657211	0.06869742
compactness_mean	0.1926213963	0.09807756	0.0523603957	-0.10413552
concavity_mean	0.0055717533	0.18521200	0.3248703785	0.04474106
concave.points_mean	-0.0094238187	0.31185243	-0.0514087968	0.08402770
symmetry_mean	-0.0869384844	0.01840673	-0.0512005770	0.01933947
fractal_dimension_mean	-0.0762718362	-0.28786888	-0.0846898562	-0.13326055
radius_se	0.0863867747	0.15027468	-0.2641253170	-0.55870157
texture_se	0.2170719674	-0.04845693	-0.0008738805	0.02426730
perimeter_se	-0.3049501584	-0.15935280	0.0900742110	0.51675039
area_se	0.1925877857	-0.06423262	0.0982150746	-0.02246072
smoothness_se	-0.0720987261	-0.05054490	-0.0598177179	0.01563119
compactness_se	-0.1403865724	0.04528769	0.0091038710	-0.12177779
concavity_se	0.0630479298	0.20521269	-0.3875423290	0.18820504
concave.points_se	0.0343753236	0.07254538	0.3517550738	-0.10966898
symmetry_se	-0.0976995265	0.08465443	-0.0423628949	0.00322620
fractal_dimension_se	0.0628432814	-0.24470508	0.0857810992	0.07519442
radius_worst	0.0072938995	0.09629821	-0.0556767923	-0.15683037
texture_worst	-0.5944401434	0.11111202	-0.0089228997	-0.11848460
perimeter_worst	-0.0920235990	-0.01722163	0.0633448296	0.23711317
area_worst	0.1467901315	0.09695982	0.1908896250	0.14406303
smoothness_worst	0.1648492374	0.06825409	0.0936901494	-0.01099014
compactness_worst	0.1813748671	-0.02967641	-0.1479209247	0.18674995
concavity_worst	-0.1321005945	-0.46042619	0.2864331353	-0.28885257
concave.points_worst	0.0008860815	-0.29984056	-0.5675277966	0.10734024
symmetry_worst	0.1627085487	-0.09714484	0.1213434508	-0.01438181
fractal_dimension_worst	-0.0923439434	0.46947115	0.0076253382	0.03782545
	PC25	PC26	PC27	PC28

radius_mean	-0.01922650	-0.129476396	-0.131526670	2.111940e-01
texture_mean	0.08474593	-0.024556664	-0.017357309	-6.581146e-05
perimeter_mean	0.02701541	-0.125255946	-0.115415423	8.433827e-02
area_mean	-0.21004078	0.362727403	0.466612477	-2.725083e-01
smoothness_mean	0.02895489	-0.037003686	0.069689923	1.479269e-03
compactness_mean	0.39662323	0.262808474	0.097748705	-5.462767e-03
concavity_mean	-0.09697732	-0.548876170	0.364808397	4.553864e-02
concave.points_mean	-0.18645160	0.387643377	-0.454699351	-8.883097e-03
symmetry_mean	-0.02458369	-0.016044038	-0.015164835	1.433026e-03
fractal_dimension_mean	-0.20722186	-0.097404839	-0.101244946	-6.311687e-03
radius_se	-0.17493043	0.049977080	0.212982901	-1.922239e-01
texture_se	0.05698648	-0.011237242	-0.010092889	-5.622611e-03
perimeter_se	0.07292764	0.103653282	0.041691553	2.631919e-01
area_se	0.13185041	-0.155304589	-0.313358657	-4.206811e-02
smoothness_se	0.03121070	-0.007717557	-0.009052154	9.792963e-03
compactness_se	0.17316455	-0.049727632	0.046536088	-1.539555e-02
concavity_se	0.01593998	0.091454968	-0.084224797	5.820978e-03
concave.points_se	-0.12954655	-0.017941919	-0.011165509	-2.900930e-02
symmetry_se	-0.01951493	-0.017267849	-0.019975983	-7.636526e-03
fractal_dimension_se	-0.08417120	0.035488974	-0.012036564	1.975646e-02
radius_worst	0.07070972	-0.197054744	-0.178666740	4.126396e-01
texture_worst	-0.11818972	0.036469433	0.021410694	-3.902509e-04
perimeter_worst	0.11803403	-0.244103670	-0.241031046	-7.286809e-01
area_worst	-0.03828995	0.231359525	0.237162466	2.389603e-01
smoothness_worst	-0.04796476	0.012602464	-0.040853568	-1.535248e-03
compactness_worst	-0.62438494	-0.100463424	-0.070505414	4.869182e-02
concavity_worst	0.11577034	0.266853781	-0.142905801	-1.764090e-02
concave.points_worst	0.26319634	-0.133574507	0.230901389	2.247567e-02
symmetry_worst	0.04529962	0.028184296	0.022790444	4.920481e-03
fractal_dimension_worst	0.28013348	0.004520482	0.059985998	-2.356214e-02
	PC29	PC30		
radius_mean	2.114605e-01	0.7024140910		
texture_mean	-1.053393e-02	0.0002736610		
perimeter_mean	3.838261e-01	-0.6898969685		
area_mean	-4.227949e-01	-0.0329473482		
smoothness_mean	-3.434667e-03	-0.0048474577		
compactness_mean	-4.101677e-02	0.0446741863		
concavity_mean	-1.001479e-02	0.0251386661		
concave.points_mean	-4.206949e-03	-0.0010772653		
symmetry_mean	-7.569862e-03	-0.0012803794		
fractal_dimension_mean	7.301433e-03	-0.0047556848		
radius_se	1.184421e-01	-0.0087110937		
texture_se	-8.776279e-03	-0.0010710392		

perimeter_se	-6.100219e-03	0.0137293906
area_se	-8.592591e-02	0.0011053260
smoothness_se	1.776386e-03	-0.0016082109
compactness_se	3.158134e-03	0.0019156224
concavity_se	1.607852e-02	-0.0089265265
concave.points_se	-2.393779e-02	-0.0021601973
symmetry_se	-5.223292e-03	0.0003293898
fractal_dimension_se	-8.341912e-03	0.0017989568
radius_worst	-6.357249e-01	-0.1356430561
texture_worst	1.723549e-02	0.0010205360
perimeter_worst	2.292180e-02	0.0797438536
area_worst	4.449359e-01	0.0397422838
smoothness_worst	7.385492e-03	0.0045832773
compactness_worst	3.566904e-06	-0.0128415624
concavity_worst	-1.267572e-02	0.0004021392
concave.points_worst	3.524045e-02	-0.0022884418
symmetry_worst	1.340423e-02	0.0003954435
fractal_dimension_worst	1.147766e-02	0.0018942925

The loading for `concave.points_mean` on the first principal component is relatively large and positive, showing that this feature contributes strongly to PC1. While a few other features like `concavity_mean`, `area_mean`, and `perimeter_mean` have similarly large loadings, none contribute substantially more than `concave.points_mean`. This indicates that PC1 is mainly influenced by tumor shape and size features.

Hierarchical clustering

The goal of this section is to do hierarchical clustering of the original data to see if there is any obvious grouping into malignant and benign clusters.

In short, these results are not good!

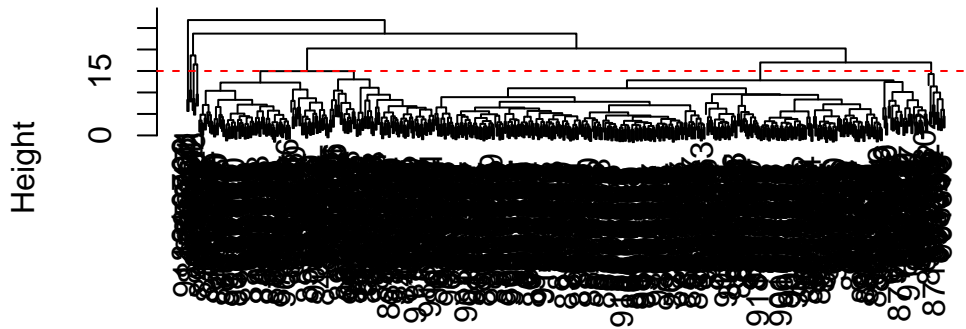
First we will scale our `wisc.data` then calculate a distance matrix, then pass to `hclust()`:

```
data.scaled <- scale(wisc.data)
data.dist <- dist(data.scaled)
wisc.hclust <- hclust(data.dist, method = "complete")
```

Q10. Using the `plot()` and `abline()` functions, what is the height at which the clustering model has 4 clusters?


```
plot(wisc.hclust)
abline(h = 15, col = "red", lty = 2)
```

Cluster Dendrogram



```
data.dist
hclust (*, "complete")
```

```
wisc.hclust.clusters <- cutree(wisc.hclust, k = 4)
```

```
table(wisc.hclust.clusters, diagnosis)
```

	diagnosis	
	B	M
wisc.hclust.clusters		
1	12	165
2	2	5
3	343	40
4	0	2

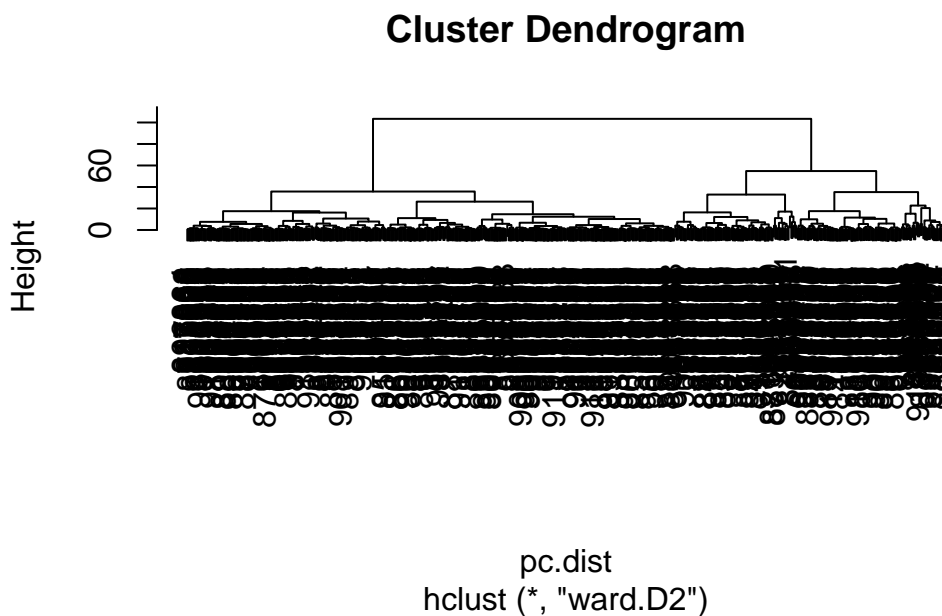
Q12. Which method gives your favorite results for the same data.dist dataset?
Explain your reasoning.

My favorite method for this dataset is ward.D2, because it creates more compact clusters and minimizes variance within each cluster. It separates malignant and benign samples better than single, complete, or average linkage, producing clusters that correspond more closely to the diagnosis.

Combining methods

The idea here is that I can take my new variable (i.e. the scores on the PCs `wisc.pr$x`) that are better descriptors of the data-set than the original features (i.e. the 30 columns in `wisc.data`) and use these as a basis for clustering.

```
pc.dist <- dist(wisc.pr$x[,1:3])
wisc.pr.hclust <- hclust(pc.dist, method= "ward.D2")
plot(wisc.pr.hclust)
```



```
grps <- cutree(wisc.pr.hclust, k=2)
table(grps)
```

```
grps
 1  2
203 366
```

```
table(diagnosis)
```

```
diagnosis
 B  M
357 212
```

I can now run `table()` with both my clustering `grps` and the expert `diagnosis`

```
table(grps, diagnosis)
```

```
      diagnosis
grps   B    M
  1  24 179
  2 333  33
```

Q13. How well does the newly created `hclust` model with two clusters separate out the two “M” and “B” diagnoses?

```
wisc.pr.hclust.clusters <- cutree(wisc.pr.hclust, k = 2)
table(wisc.pr.hclust.clusters, diagnosis)
```

```
      diagnosis
wisc.pr.hclust.clusters  B    M
      1  24 179
      2 333  33
```

Q14. How well do the hierarchical clustering models you created in the previous sections (i.e. without first doing PCA) do in terms of separating the diagnoses? Again, use the `table()` function to compare the output of each model (`wisc.hclust.clusters` and `wisc.pr.hclust.clusters`) with the vector containing the actual diagnoses.

```
wisc.hclust.clusters <- cutree(wisc.hclust, k = 4)
table(wisc.hclust.clusters, diagnosis)
```

```
      diagnosis
wisc.hclust.clusters  B    M
      1  12 165
      2   2   5
      3 343  40
      4   0   2
```

Our cluster “1” has 179 “M” diagnosis or cluster “2” has 333 “B” diagnosis

179 TP 24 FP 333 TN 33 FN

Sensitivity: $TP/(TP+FN)$

```
179/(179+33)
```

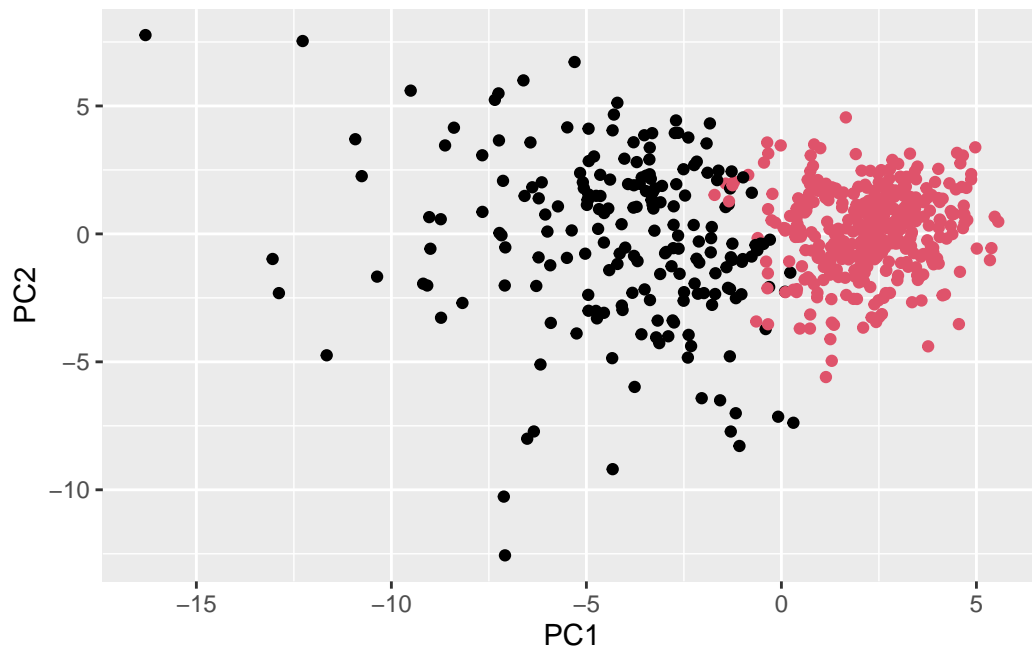
```
[1] 0.8443396
```

Specificity: $TN/(TN+FP)$

```
333/(333 + 24)
```

```
[1] 0.9327731
```

```
ggplot(wisc.pr$x) +  
  aes(PC1, PC2) +  
  geom_point(col=grps)
```



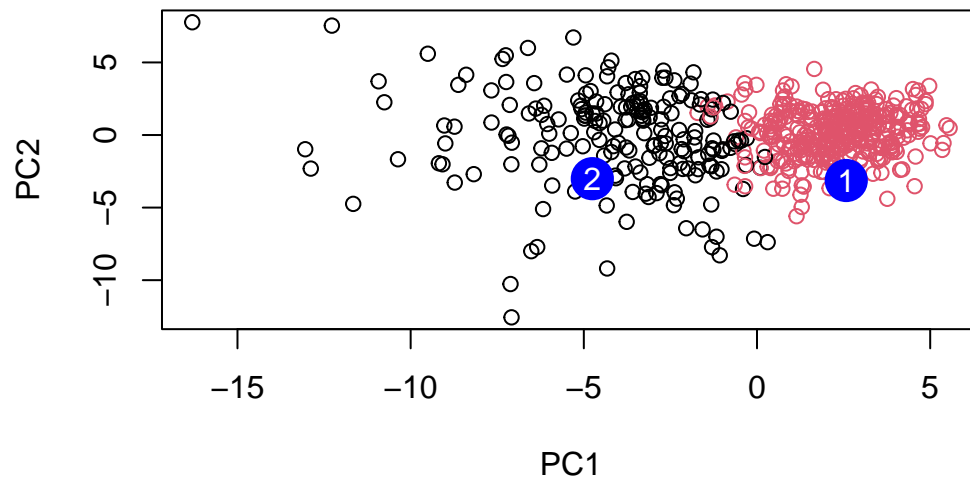
Prediction

We can use our PCA model for prediction of new un-seen cases:

```
url <- "https://tinyurl.com/new-samples-CSV"
new <- read.csv(url)
npc <- predict(wisc.pr, newdata=new)
npc
```

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
[1,]	2.576616	-3.135913	1.3990492	-0.7631950	2.781648	-0.8150185	-0.3959098
[2,]	-4.754928	-3.009033	-0.1660946	-0.6052952	-1.140698	-1.2189945	0.8193031
	PC8	PC9	PC10	PC11	PC12	PC13	PC14
[1,]	-0.2307350	0.1029569	-0.9272861	0.3411457	0.375921	0.1610764	1.187882
[2,]	-0.3307423	0.5281896	-0.4855301	0.7173233	-1.185917	0.5893856	0.303029
	PC15	PC16	PC17	PC18	PC19	PC20	
[1,]	0.3216974	-0.1743616	-0.07875393	-0.11207028	-0.08802955	-0.2495216	
[2,]	0.1299153	0.1448061	-0.40509706	0.06565549	0.25591230	-0.4289500	
	PC21	PC22	PC23	PC24	PC25	PC26	
[1,]	0.1228233	0.09358453	0.08347651	0.1223396	0.02124121	0.078884581	
[2,]	-0.1224776	0.01732146	0.06316631	-0.2338618	-0.20755948	-0.009833238	
	PC27	PC28	PC29	PC30			
[1,]	0.220199544	-0.02946023	-0.015620933	0.005269029			
[2,]	-0.001134152	0.09638361	0.002795349	-0.019015820			

```
plot(wisc.pr$x[,1:2], col=grps)
points(npc[,1], npc[,2], col="blue", pch=16, cex=3)
text(npc[,1], npc[,2], c(1,2), col="white")
```



Q16. Which of these new patients should we prioritize for follow up based on your results?

New patients assigned to cluster 1 are most likely malignant based on the PCA + hierarchical clustering model.